MECHANICAL DESIGN OF NEW DUAL PINHOLE MINI-BEAM COLLIMATOR WITH MOTORIZED PITCH AND YAW ADJUSTER PROVIDES LOWER BACKGROUND FOR X-RAY CRYSTALLOGRAPHY AT GMCA@APS

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With my colleagues at GM/CA CAT
Robert R. Fischetti, Naga Venugopalan, Oleg Makarov, and Sergey Stepanov

Outline

- GMCA mini-beam, rastering and vector data-collection tool
- Design history of compact mini beam collimators
- New mini-beam collimator with small exit apertures provides lower background
- Collimator positioning system with motorized pitch and yaw adjuster
The GM/CA-developed, quad-mini-beam collimator, advanced rastering and vector data-collection software tools, have enabled successful data collection on some of the most challenging problems in structural biology.
A novel hard X-Ray Quad Collimator system for micro-crystallography experiments in structural biology

Key technical advantages include highly reproducible, automated exchange between various mini-beams and the full focused beam within a few seconds.

Mini-beam collimator enables Micro-crystallography experiments on standard beamlines.

Quad mini-beam collimator: 5, 10, 20-\(\mu\)m beams and 300-\(\mu\)m scatter guard
Rapid beam size selection — pioneered at GM/CA

**Quad mini-beam collimator**
- match beam and crystal size
- use small beam to probe large crystal

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<thead>
<tr>
<th>Beam size FWHM (μm)</th>
<th>Intensity (Ph./sec)</th>
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<tbody>
<tr>
<td>20 x 65</td>
<td>$2.0 \times 10^{13}$</td>
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<td>20 Ø</td>
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Image of beam at sample position on YAG crystal
Rapid beam size selection – pioneered at GM/CA

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JBlulce-EPICS GUI
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Image of beam at sample position on YAG crystal
Advanced rastering and vector data-collection software tools

Finding/centering sample crystals

Rastering/mapping crystal quality

Data-collection tab

Vector data collection.
Design history of compact mini beam collimators

Feb 2007 single
Feb 2008 dual and triple
Feb 2009 robust triple
Jul 2009 quad prototype
April 2015 Dual, quad
Pitch and yaw

Motivation
• Provide small beam to match diffracting volume
• Stable beam
• Low background scatter
• Sample visualization
2015 developing dual-pinhole collimator with small exit apertures provides lower background

Improved

Reduce Background

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<tr>
<th>Collimator</th>
<th>Beam Defining pinhole ($\mu m$)</th>
<th>Exit Aperture (EDM) ($\mu m$)</th>
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<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>250 EDM</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>250 EDM</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
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</tr>
<tr>
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<td>300</td>
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<td>100</td>
</tr>
<tr>
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<td>150</td>
<td>300</td>
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Improved

Reduce Background
New Dual-pinhole Quad mini-beam collimator

Sample

Single beam path

Cap - back scatter guard with entrance pinhole

Scatter guard body

X-ray beam

Pinhole - beam Defining aperture (5, 10, 20 and 150 μm)

Forward scatter guard

Four beam path channels

One 300μm exit pinhole for Full beam

50, 70, 100 μm exit pinhole for 5, 10, 20μ mini beam, respectively
Background - Full beam: 150/300 Vs 300/600

150µm/300µm

300µm/600µm

Background scattering
Decreased by 27%

Background scatter: 5/50 Vs 5/250

5µm/50µm

5µm/250µm

Background scattering
Decreased by 60%
Added Exit Cap to Remove Metallic Rings

Cap - Exit scatter guard with exit pinhole

Cap - back scatter guard with entrance pinhole

Sample

Single beam path

5µm/50µm

Nagarajan Venugopalan
Faint metallic rings escaped exit aperture

Sample

Cap - Exit scatter guard with exit pinhole

Cap - back scatter guard with entrance pinhole

Single beam path

5 µm/50 µm

Nagarajan Venugopalan
Added Exit Cap to Remove Metallic Rings

Faint metallic rings escaped exit aperture

Sample

Cap - Exit scatter guard with exit pinhole

Single beam path

Cap - back scatter guard with entrance pinhole
Collimator as installed at the beamline endstation

 Beam direction

March 2015

Exit scatter cap

November 2015

View of sample

April 2016

Robust

ID-D – Station

ID-B – Station
Collimator positioning system with motorized pitch and yaw adjuster

New Quad collimator Alignment

The motorized pitch and yaw motions made alignment of each beam defining/exit aperture combination relatively easy. The two translational and two angular motions were highly reproducible.

Independent angular adjustments for each collimator Translational X and Y positions and angular pitch and yaw are stored Translational and angular positions recalled to provide desired beam size.
Conclusion

• Systematic reduction in background as we reduce the size of the exit aperture.

• Over all background reduced by 27% for the full beam (from 300/600 to 150/300).

• Over all background reduced by 60% for the 5mm beam (from 5/250 to 5/50).
Acknowledgements

GM/CA colleagues:

Robert R. Fischetti
Group Leader
Design

Naga Venugopalan
Crystallographer
Design, installation and alignment

Oleg Makarov
Control Systems Developer
Hardware and controls

Sergey Stepanov
Control Systems Sector Leader
Controls and software

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Thank you for your attention!